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Technology & Development Program

Price Field Office

5100 Fire
October 2002

Price Canyon Fire Entrapment Investigation Report

June 30, 2002

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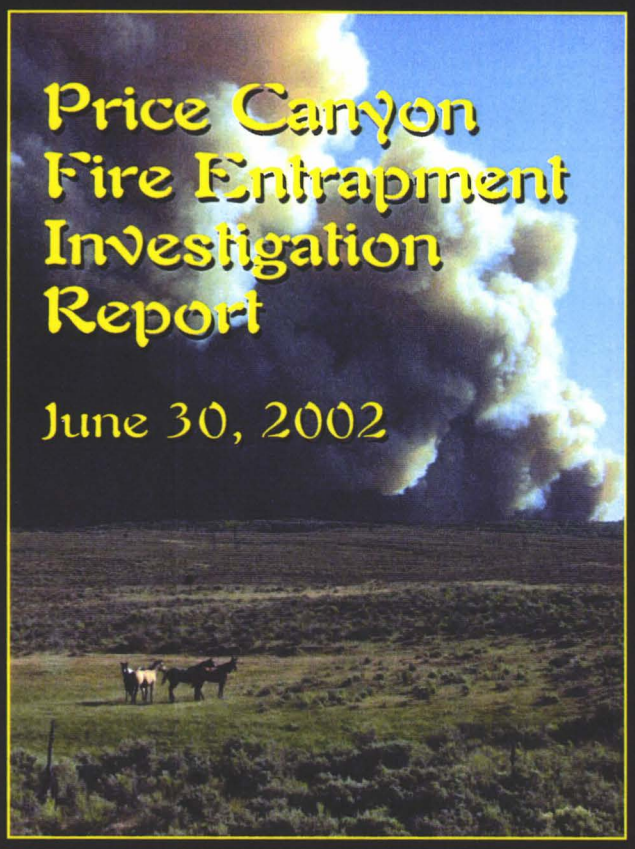

USDI Bureau of Land Management
Price Field Office
Price, UT

USDA Forest Service
Technology and Development Program
Missoula, MT

October 2002

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Utah Fuel Management Demonstration project

Many people contributed in one way or another to this analysis. However, it should be noted that the final interpretations are solely the responsibility of the Price Canyon fire investigation team.

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Executive Summary

On Sunday, June 30, 2002, a wildland fire was reported on Bureau of Land Management (BLM) land 14 miles northwest of Price, UT. The initial attack response included a type III incident commander, several fire engines, dozers, airtankers, a type III helicopter, and eight smokejumpers. When the incident commander (IC) and some of the engines arrived on the fire at about 1500, the fire was about 25 acres and growing rapidly. Extremely dry fuels, moderate winds, steep slopes, and deeply dissected drainages all indicated the potential for extreme fire behavior. It was determined afterward that a passing railroad train had started the fire.

The smokejumpers arrived on the fire at about 1700. Shortly afterward, they initiated a firing operation to create a safety zone for them and their gear, and to help secure the north end of the fire. At about 1900, five of the smokejumpers regrouped at an intersection of two-track dirt roads that had been used as the jump spot. Fire behavior in the bowl and on the plateau to their southwest was becoming increasingly active and they were taking measures to ensure that their jump gear was secure.

With virtually no warning, the smoke column from the southwest, which had been going up and over the five jumpers, surfaced at their location. The jumpers reported that winds instantly increased to over 50 miles per hour. Debris "as big as softballs" and embers rained down around them, and dense smoke enveloped them. The fire on the plateau to the southwest of the jumpers was described as a "river of fire" advancing toward them.

Two of the jumpers ran toward the east on a two-track road that had been used as a control line for the firing operation, came a short distance back toward the intersection, then moved into the black and deployed fire shelters. The three other jumpers in this group escaped to the north, eventually reaching a paved road. The two jumpers who stayed in the black were exposed to several surges of strong winds, smoke, and showers of debris and embers for a period of 30 to 40 minutes. They alternated between being completely prone under their shelters to standing or kneeling with their shelters draped over them.

After the fire event was over, all of the smokejumpers returned to work on the fire. They regrouped and tied in with other resources on the fire, and worked until they bedded down around midnight. The jumpers talked among themselves about the fire event and shelter deployment, but the incident commander was not informed that a deployment had occurred.

On July 1, Moab dispatch was informed by BLM Boise smokejumper supervisor Hector Madrid that two smokejumpers had deployed fire shelters on the Price Canyon fire the previous day. Moab dispatch asked the incident commander to confirm this with the jumpers, and confirmed that two jumpers had deployed fire shelters. This information was shared with the Price field office, and the process for conducting an entrapment investigation was initiated. An entrapment investigation team was assigned on July 2. Glenn Carpenter of the Salt Lake City field office of the BLM was designated as leader of the team. The entrapment investigation team arrived in Salt Lake City on July 3 and began their investigation at 1200.

Among other findings, the team determined that:

- Fire behavior indicators predicted the potential for extreme fire behavior on the Price Canyon fire.
- A transition from a qualified type III incident commander to another type III incident commander occurred at a critical phase of the fire and hampered control of the incident.
- Line-of-sight tactical radio frequencies used were insufficient to maintain positive communications between all resources on the incident. There was not a repeater accessible to firefighters nor was a "human repeater" assigned to facilitate communications.
- The jumpers discussed the potential for expansion of the fire into the west bowl. They noted that if fire entered the bowl, it could pose a problem for firefighters on the plateau. There was no lookout posted who could see into the bowl or inform firefighters of danger from that area.
- The entrapment was caused by the collapse of the column that had emerged onto the plateau from the west bowl.
- The smoke column produced by the smokejumpers' firing operation probably helped accelerate the fire rate of spread in the area west of their position and exacerbated conditions at the deployment site.
- The deployment of fire shelters by two jumpers was not reported immediately to the incident commander.

Sequence of Events

On Sunday, June 30, 2002, at 1400 hours, a wildland fire was reported on Bureau of Land Management land 14 miles northwest of Price, UT. The size of the fire was initially estimated to be 100 square yards. Fuels in the fire area were a mixture of grass, sage, pinyon pine, juniper, oak brush, aspen, and Douglas fir. The fire started in the bottom of Price Canyon and burned up the side drainage and steep slopes of Sulphur Canyon (figure 1). Extremely dry fuels and weather conditions were conducive to extreme fire behavior. Prevailing winds in the area were out of the west at 5 to 15 miles per hour.

The initial attack response included type III incident commander Dalynn Parks, two Forest Service (FS) engines, one BLM engine, one Price volunteer fire department engine, dozers, airtankers, a type III helicopter, and eight smokejumpers. IC Parks and some of the engines arrived on the fire at about 1500. The fire's estimated size then was about 25 acres. After helicopter 45Y arrived at the incident at around 1600, IC Parks went for a reconnaissance flight.

A plane load of eight smokejumpers was dispatched from Cedar City, UT, with four Boise BLM jumpers and four FS jumpers (two each from Missoula, MT, and McCall, ID). The aircraft arrived over the incident at about 1630 and received instructions from IC Parks to drop jumpers on the plateau north of the fire. While the plane was circling the fire, the jumpers could see a large, steep bowl with heavy fuels on the west side of the fire (figure 2). Some of the jumpers discussed this and they noted that if the fire crossed the spur ridge that separated the fire from the west bowl, the entire bowl would probably be consumed by fire and could become a problem.

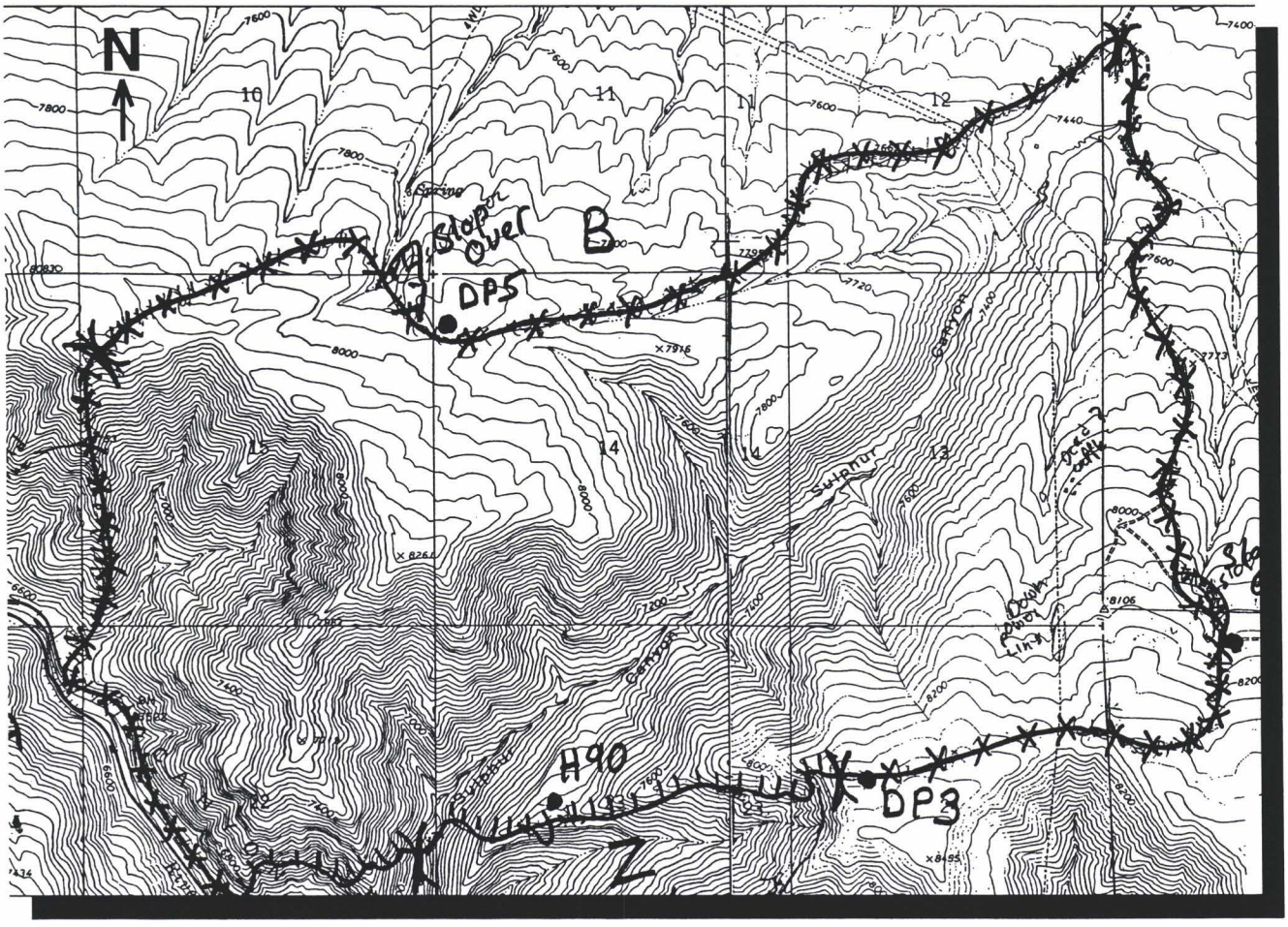

Figure 1—The Price Canyon fire terrain and perimeter .

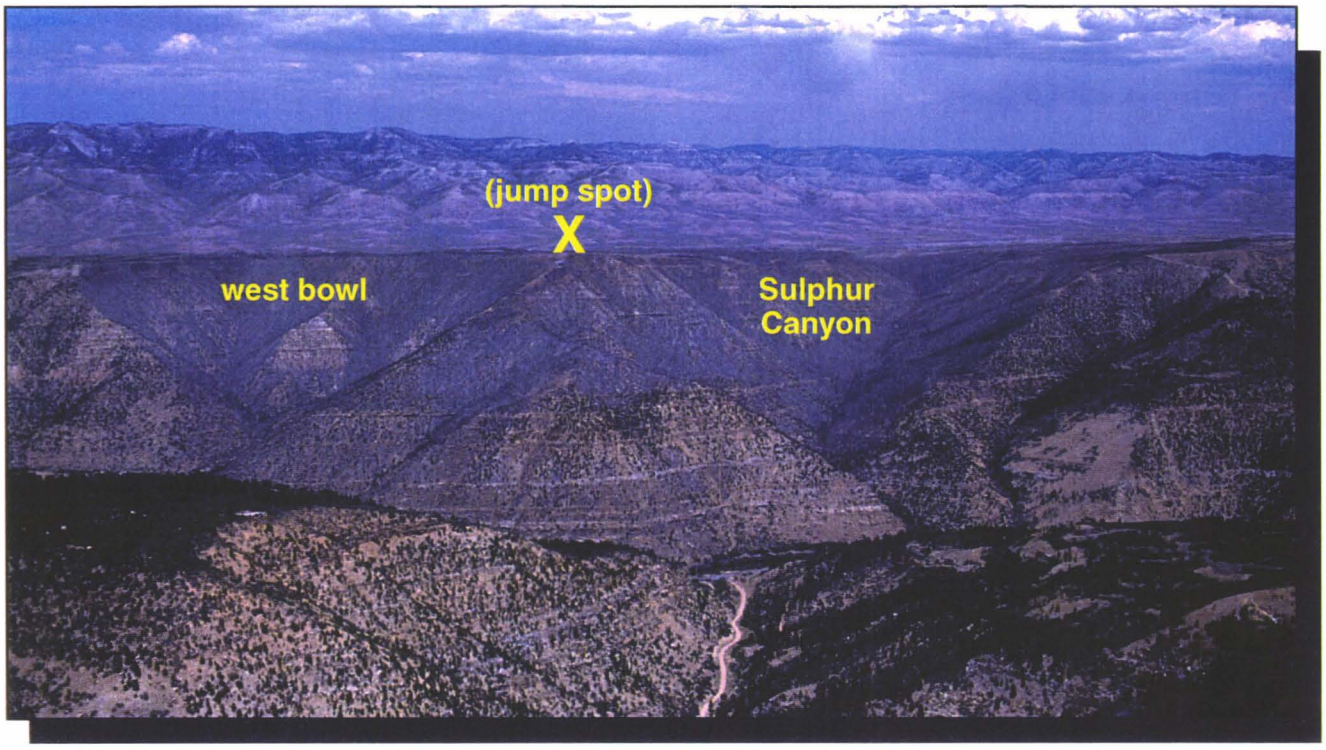

Figure 2—The west bowl and Sulphur Canyon.

A jump spot was selected about ½ mile north of the fire at an intersection of two-track dirt roads, and all eight smokejumpers were on the ground by 1700. The BLM and FS jumpers were dropped in two separate groups at different elevations because of the different operational requirements of each agency's parachutes. The jumper-in-charge (JIC), Shannon Orr, contacted IC Parks and informed him that the jumpers wanted to begin a firing operation to create a safety zone for the jumpers and their gear and to help secure the north end of the fire. They received permission to do so.

As the jumpers arrived, command of the incident was transitioning to a second type III incident commander. Former IC Parks was reassigned as a dozer boss. At about 1800, the new incident commander, Leanard Garcia, was at the helibase several miles from the fire and was preparing to go on a reconnaissance flight in helicopter 45Y. By this time, the fire was an estimated 300 to 500 acres and still growing.

After the jumpers conducted a briefing, they used fusees to begin firing the area to the southeast of the two-track road intersection. Initially, jumpers John Simas, Steve Reed, Jim Duzak, and Matt Loe began firing the south side of the road that headed east from the road intersection (figure 3). Jumpers Tom Dwyer and Pete Briant began firing the east side of the two-track road that headed south from the intersection. Tom Dwyer also served as a lookout for the jumpers' firing operation. JIC Orr and jumper Barry Burris remained near the jump spot. IC Garcia, who was now on a reconnaissance flight in helicopter 45Y, observed the jumpers' firing operation and told them he approved of what they were doing.

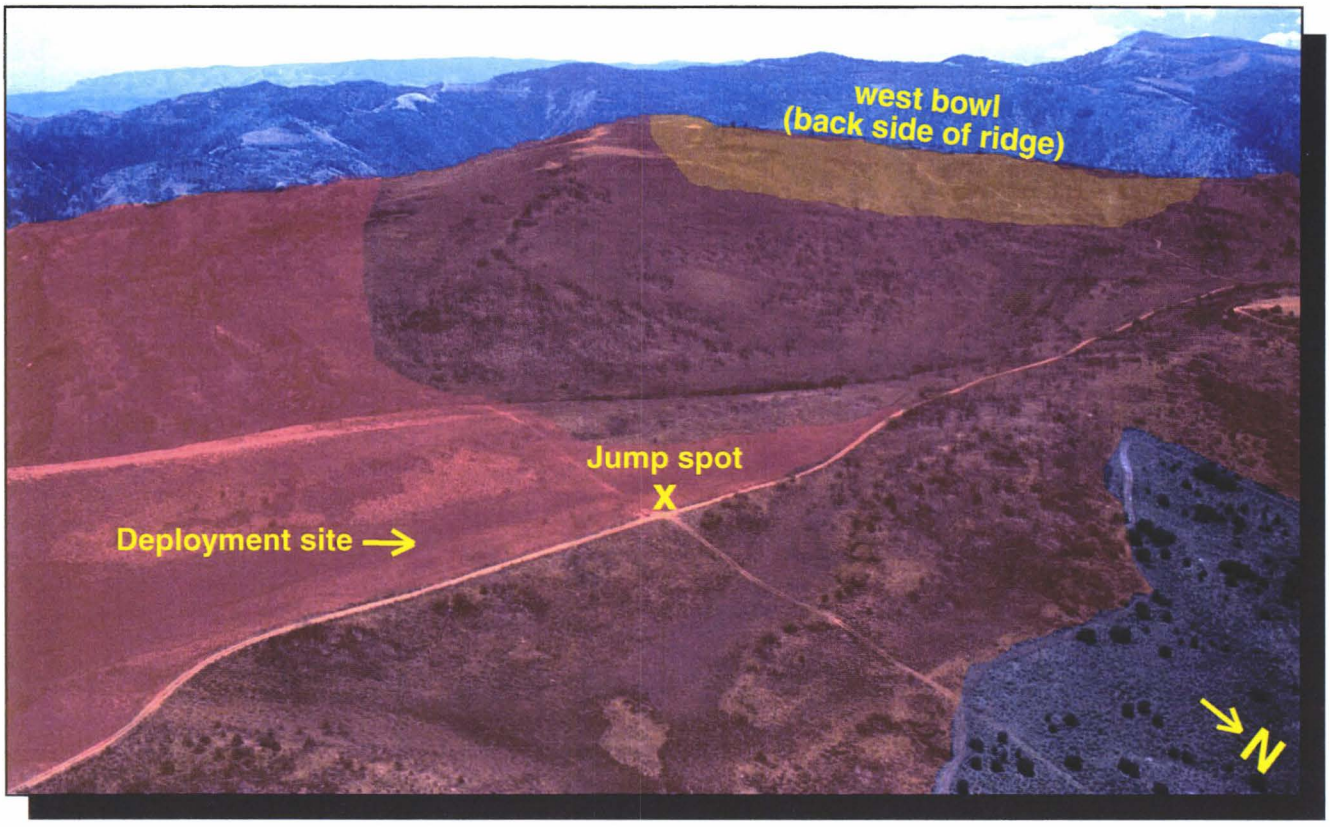

Figure 3—Fire events: RED is the area burned by jumpers; YELLOW is the fire emerging onto the plateau from the west bowl on the back side of the ridge; and BROWN is the fire after column collapse occurred.

At about 1830, fire activity to the southwest of the jump spot was becoming increasingly threatening (figures 4 and 5). Loe, who had been firing the east road, returned to the jump spot because he ran out of fusees. JIC Orr instructed Loe to begin firing the south side of the road that headed west from the intersection.

At about 1845, after firing along the road several hundred feet toward the west, Loe ran out of fusees and returned to the jump spot. JIC Orr called Briant and Dwyer, who had been firing a line extending south from the road intersection, and told them to return to the jump spot. Simas, Reed, and Duzak continued firing along the east road.

At about 1900, JIC Orr, Briant, Loe, Dwyer, and Burris were back at the jump spot road intersection. A dense, black smoke column was coming from the bowl (figure 6) and canyon rim to the southwest of them. The five jumpers could see that this part of the fire was advancing downhill in their direction and fire whirls were observed at this time. To prevent their jump gear and paracargo from being consumed by the approaching fire, they decided to move all of their gear into the burned (red) area.

In a matter of seconds, the column from the bowl appeared to collapse on the five jumpers. Winds suddenly increased to an estimated 50+ miles per hour. What they described as a "river of fire" advanced toward them from the southwest. Dense black smoke enveloped the jumpers, and "softball-sized" debris and embers rained down around them (figure 7).

Figure 4—Fire emerging onto the plateau from the west bowl. The fire in the foreground was the end of smokejumper Matt Loe's burnout west of the road intersection.

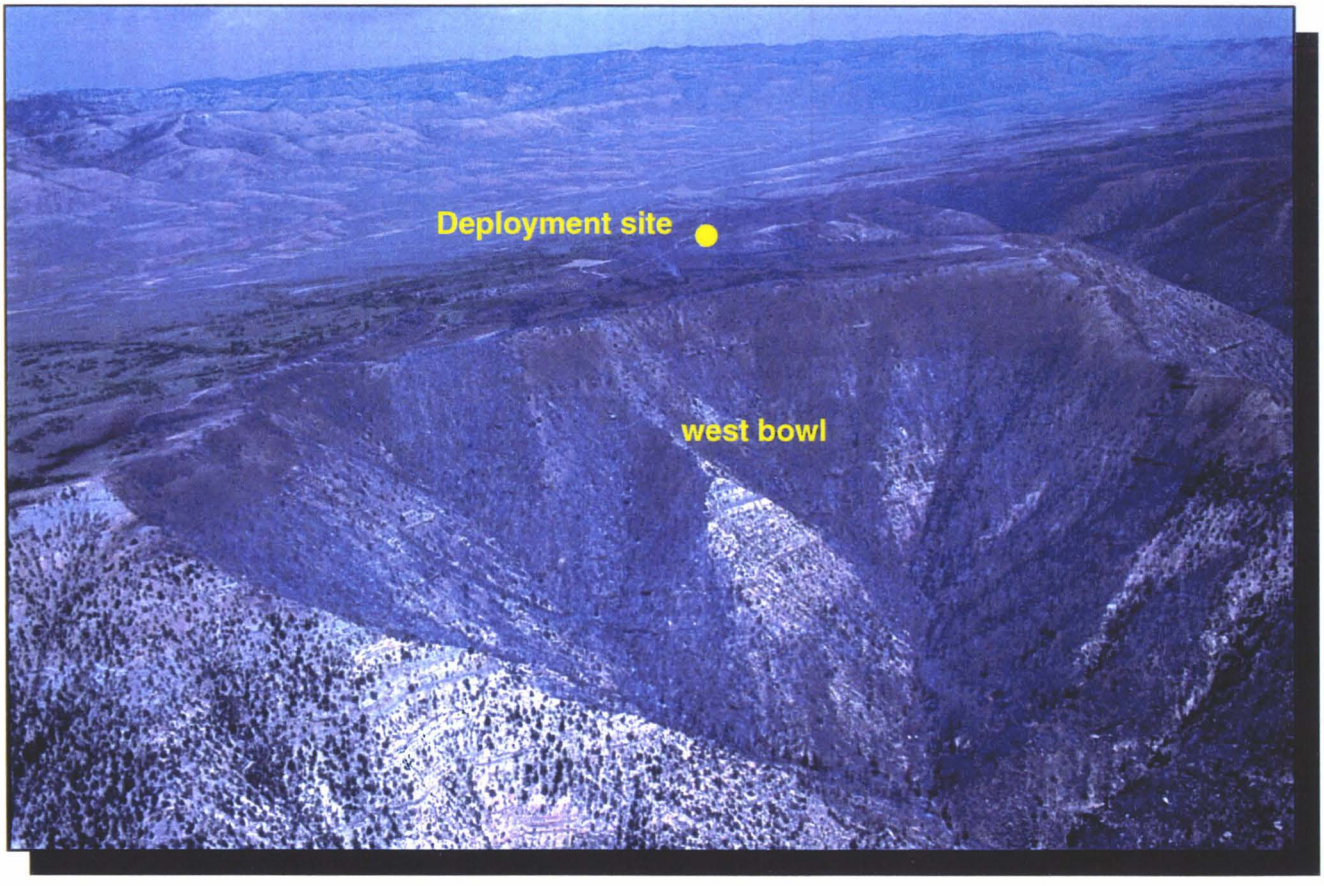

Figure 5—West bowl, plateau, and deployment site.

Figure 6—Column from the smokejumpers' firing operation (lighter smoke, left) and the fire column from the west bowl (darker, right).

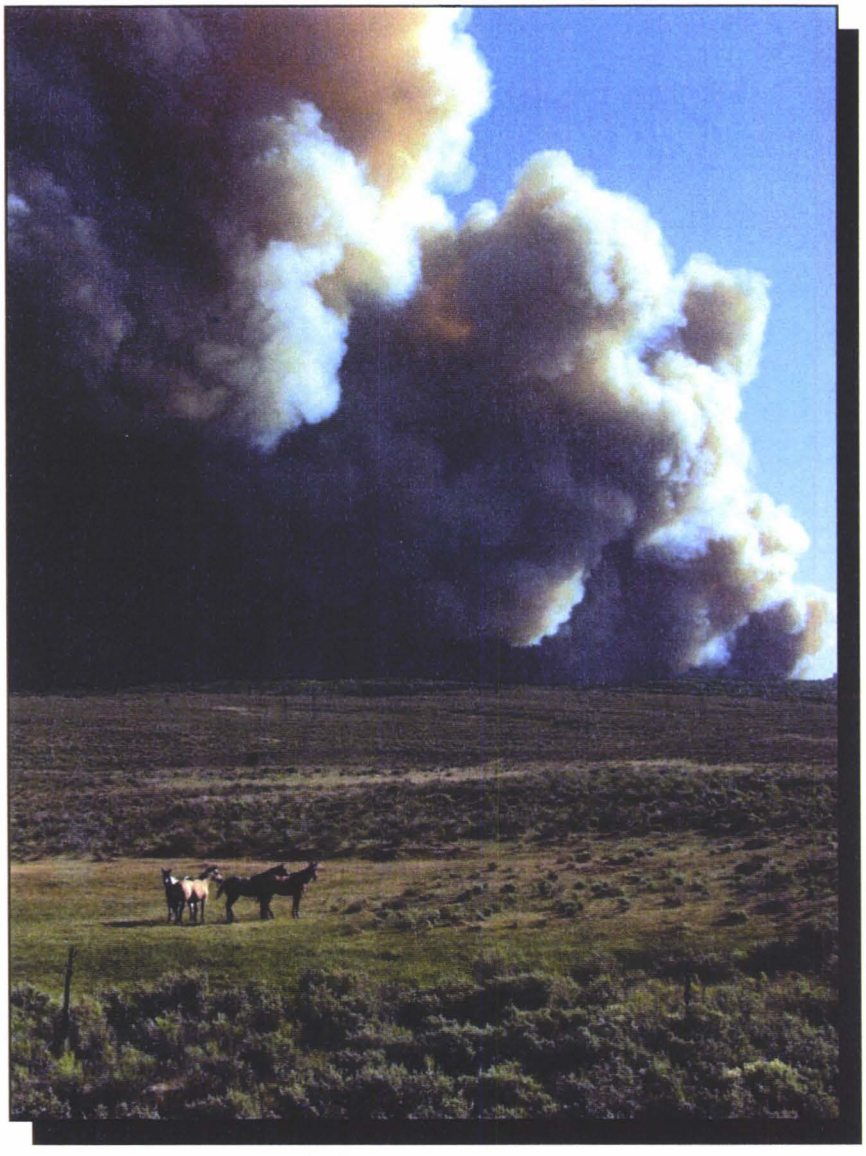

Figure 7—West end of the fire after column collapse.

All five jumpers immediately began running. Dwyer and Loe ran toward the east down the two-track road that had been used as a control line for the firing operation (figure 8). After running for about 20 yards, Dwyer was forced to kneel for a moment so that he could catch a breath of clean air. Dwyer and Loe continued running, and soon the conditions became slightly less severe. They walked back toward the road intersection. By then, the fire was burning on the north side of the east-west road and visibility was extremely limited by the heavy smoke. They walked into the burned area on the south side of the road about 150 feet from the road intersection. After a brief discussion, they used their handtools to scrape an area to mineral soil and remove remnants of burning sagebrush. They deployed their fire shelters and got inside, each taking their radio and a canteen of water with them. Dwyer and Loe stated that they observed fire whirls and extreme, erratic fire behavior nearby.

JIC Orr and Briant ran from the intersection toward the north on a two-track road. Initially, they were pelted with debris and embers as they ran through unburned fuels toward a paved road about two miles away. After a short distance, they emerged from underneath the column and conditions improved considerably. Before they emerged from under the smoke column, Orr and Briant felt they couldn't pause long enough even to remove packs or get their fire shelters out for fear of being overcome by the fire.

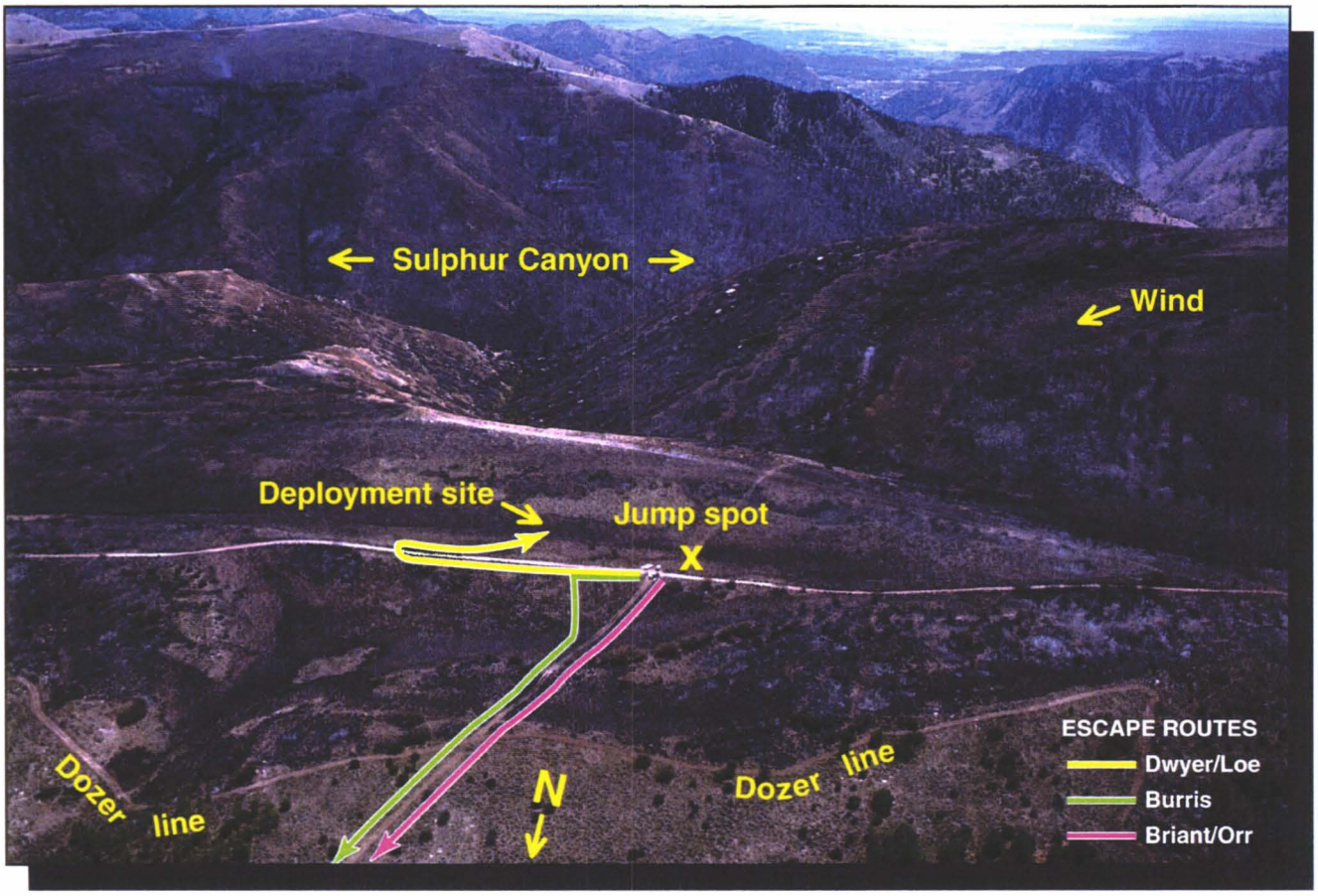

Figure 8—Deployment site and escape routes.

Burris initially ran down the road toward the east with Dwyer and Loe, then decided to run toward the north through the sagebrush to join Orr and Briant. After a short distance, he fell, got up, and discarded his pack (figure 9) and fire shelter. Orr stated afterward that he saw Burris fall, but continued running because he felt his own life was in imminent danger. Burris lost his hardhat and sunglasses while running to join Orr and Briant, who were heading north on the two-track road. The three jumpers continued running until they reached the paved road. Orr, Briant, and Burris described the first few minutes of this event as frightening and felt that they were running for their lives.

At the time these events were occurring, Simas, Reed, and Duzak continued firing the east road and were unaware of the extreme conditions that the other jumpers were experiencing. From their perspective, the burnout on the east road was working well and was securing the north flank of the fire.

For about the next 30 to 40 minutes, Dwyer and Loe stayed under their shelters. Most of the time they were kneeling or standing while facing the oncoming fire. They were subjected to several intense blasts of smoke, hot air, debris, and embers. They could detect when another blast was arriving. Each time, they lay prone on the ground underneath their shelters until the conditions subsided enough for them to stand up. Although their shelters were not damaged by direct flame, Loe's shelter had about an 18-inch section of sewn seam come apart. It was later determined that this defect was due to a failure by the shelter assembler to capture that section of the shelter's sod cloth in the sewn seam. It did not appear that the shelter defect diminished the shelter's protective capability in this instance.

Dwyer and Loe tried to radio the other jumpers to let them know they were safe, but they were initially unable to make contact with anyone else. After about 20 min-

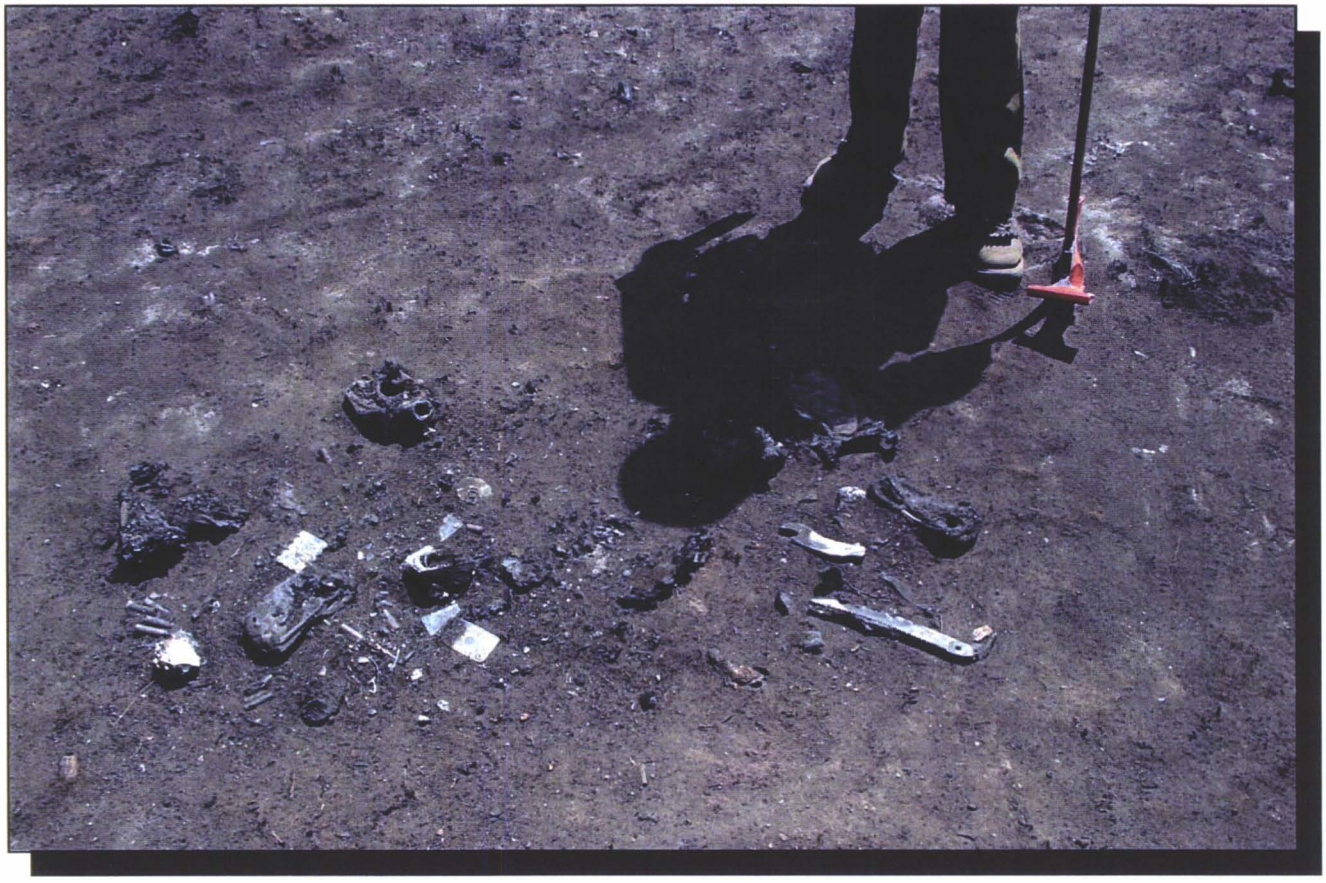

Figure 9—Remnants of smokejumper Burris' burned pack.

utes, Loe contacted the air tactical group supervisor (ATGS) who had just arrived at the incident. Loe informed him that they had gone into the black to take refuge and asked him to relay that message to JIC Orr. This was done. Loe stated afterward that he had told the ATGS that he and Dwyer had shelters out and were okay, but the ATGS was unable to recall any mention of fire shelters from that conversation. Loe asked the ATGS if the helicopter could drop a bucket of water on their jump gear, but was informed that the column obscured their location and that a bucket drop was not possible. The ATGS also informed IC Garcia that three jumpers had run toward the paved road and two jumpers had taken refuge in the black and that everyone was okay.

Afterward, Dwyer and Loe said they felt they would have survived where they were without shelters, but the shelters protected them from burning embers, made it easier to breathe when the blasts of smoke and hot air impacted them, and increased their level of comfort.

At about 1930, conditions subsided enough for Dwyer to leave his shelter and return to the jump spot. He found two sets of jump gear, cargo chutes, and fireboxes burning. He moved the remaining unburned gear to prevent it from being consumed by fire. Conditions continued to improve, and at about 2000, Dwyer and Loe refolded their fire shelters and put them back in their packs. Later on, they exchanged their used shelters for new shelters from a Forest Service engine.

When they arrived at the paved road shortly after 1900, JIC Orr, Briant, and Burris met a civilian who transported them to the area where Simas, Reed, and Duzak were completing their burnout. Burris borrowed a hardhat, line gear, water, and a fire shelter from a Forest Service engine working in the area. Burris then began working with Reed and assisted with the firing operation. Orr and

Briant walked up the road to the jump spot and met Dwyer and Loe. They discussed what had happened and took a short break, then all four walked back down the east road to tie in with the other jumpers. The jumpers worked until about midnight before bedding down for the night.

On July 1, at about 0800, Moab dispatch received a phone call from jumper Hector Madrid at the Boise BLM smokejumper base. Madrid informed them that fire shelters had been deployed by jumpers on the Price Canyon fire the previous day, and Moab dispatch contacted IC Garcia to see if he could confirm this. Garcia met with Dwyer, Loe, and Orr and was informed that Dwyer and Loe had deployed shelters "as shields from the embers and heat." Garcia relayed this information to Moab dispatch.

The eight jumpers worked on the fire for part of the day and were released on July 1 to return to Cedar City.

Fire Behavior Analysis

The objective of this fire behavior analysis is to describe the fire environment before and during the Price Canyon fire entrapment on June 30, 2002. Standard fire behavior prediction techniques used by both fire behavior analysts (FBANs) and firefighters were used to develop this report. Much of the fire behavior information presented here came from interviews with fire personnel, the study and interpretation of photographs taken during and after the fire, and from a field trip to the fire site to gather information for a FARSITE (computer program) fire behavior run. Since the fire was contained when the investigation team arrived, actual fire behavior wasn't observed.

Fire danger, drought, and weather information were obtained and verified using information from the National Interagency Fire Center (NIFC), Boise, ID; the National Weather Service in Salt Lake City, UT; and Web-based tools at the Fire Sciences Laboratory in Missoula, MT. A FARSITE run was completed using fuel models developed for the Southern Utah Fuels Demonstration project.

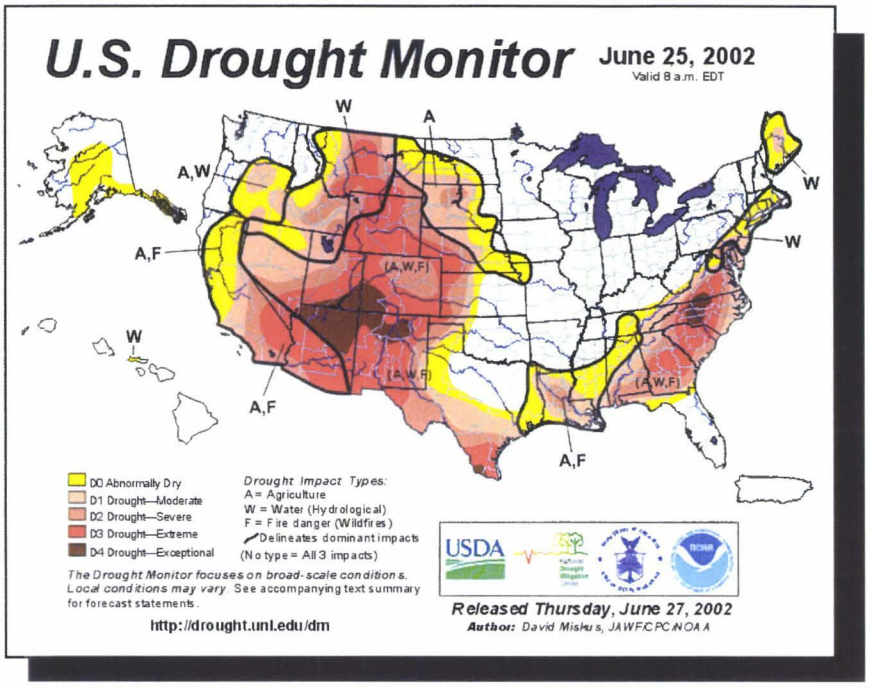

Figure 10—U.S. Drought Monitor map, June 25, 2002.

Conditions Before the Entrapment

Southeastern Utah had been in an extended drought. The Price Canyon fire area was classified as being in a "severe-to-extreme drought." The Palmer drought index indicated that 2002 was one of the severest droughts in Utah since 1895. The U.S. Drought Monitor report for June 25, 2002 (figure 10), typed Price, UT and the surrounding area as being in an "exceptional drought."

The fire danger class map generated by the National Fire Danger Rating System (NFDRS) for June 30 and issued by the National Interagency Fire Center indicated extreme burning conditions. A map (commonly called a 'greenness' map) generated at the Missoula fire lab from the NVDI program shows the fuels in the Price Canyon fire area as being in a moisture deficit, being 50 to 75 percent as green as normal for that time of year.

Figure 11 shows the burning index (BI), energy release component (ERC) and 1,000-hour fuel moistures for three fire danger fuel classes, H (short-needled conifers), G (dense conifer stands) and F (oakbrush fields and open stands of pinyon-juniper). These indexes were calculated using weather observations from the Joe's Valley remote automatic weather station (RAWS), located 35 miles southwest of the entrapment site.

Fuel model	BI	ERC	1,000-hour fuel moisture
H	45	63	4
G	100	106	4
F	80	160	4

Figure 11—Burning index (BI), energy release component (ERC), and 1,000-hour fuel moisture for Joe's Valley RAWS station (8,700-foot elevation) for June 30, 2002, at 1300 hours.

Conditions the Day of the Entrapment

Fire Weather—The National Weather Service in Salt Lake City issued a morning fire weather forecast for central Utah and fire weather zone 431 at 0830 on June 30, 2002. This forecast predicted "relative humidity will remain very low" with "unseasonably warm temperatures through midweek." Specific weather predictions from the forecast are summarized in figure 12.

Temperature: 80 to 88 °F
Relative humidity: 11 to 21 percent
Haines index: 5
Chance wetting rain: 0 percent
LAL: 1
Wind (20ft):
- Slope valley: Upslope and upvalley 4 to 10 mph
- Ridgetops: West/northwest 10 to 20 mph, gusting to 30.

Figure 12—Fire weather forecast for June 30, 2002.

The Joe's Valley RAWS was used to analyze weather conditions throughout the day of the smokejumper entrapment for June 30. Figure 13 shows this weather information.

Figure 13—Weather observations at 8,700 feet from the Joe's Valley RAWS on June 30, 2002.

Time	Temperature (°F)	Relative humidity	Average windspeed (mph)	Wind direction (degrees)
0001	69	7	18	272
0003	68	7	12	283
0005	66	9	9	287
0007	69	8	9	357
0009	74	7	9	263
1100	75	7	13	294
1300	81	6	9	268
1500	80	5	11	274
1700	80	4	12	289
1900	72	7	5	294
2100	68	9	7	299

Fuels—The fuel type in a particular area of the fire depended mainly on topography, particularly a combination of the exposure of the slope and its elevation.

The entrapment area, a relatively flat plateau above the west bowl, consisted mainly of sagebrush/grass with isolated clumps of oak brush, mahogany and pockets of aspen.

Much of the sagebrush/grass fuel type was grazed. The west bowl fuels consisted of some Douglas fir on the north exposures in the canyon, and juniper with a broken grass understory in the main canyons and draws.

Fuels in Sulphur Canyon consisted mostly of juniper, oakbrush, and sagebrush/grass, with intermittent stringers of Douglas fir and aspen. The primary carrier of the fire was grass.

Standardized BEHAVE fuel models (FM) 2 and 6 are commonly used for fire behavior predictions in these fuel types. In FM 2 fuels, the fire is spread primarily through the fine herbaceous fuels. Clumps of fuels might produce higher intensities. Fire is carried in the surface fuels made up of litter cast by shrubs and forbs in the understory.

In FM 6 fuels, fires carry through the shrub layer although the fire requires wind to carry it.

Fuel moistures were very low, with 1-hour time-lag fuels reported to be at 1 percent and 1,000-hour time-lag fuels at 4 percent. Figure 14 measures live fuel moistures taken from BLM live fuel moisture sampling sites near the fire area.

Species	Live fuel moisture (percent)
Douglas fir	83
Juniper	70 to 72
Sage	68 to 121

Figure 14—Live fuel moistures of selected species in the Price Canyon area.

The Nevada BLM live fuel-moisture Web page indicates that when live fuel moistures range between 75 and 100 percent, "fires will exhibit extreme fire behavior" with high rates of spread and spotting.

Topography—The topography of the Price Canyon wildland fire area is classified as a canyon/plateau landscape with steep dissected canyons that give way to relatively flat plateaus dominated by sagebrush (figure 14). The major canyons (west bowl and Sulphur Canyon) intersect with smaller side drainages.

The difference in elevation between the fire's starting point at the railroad track in Price Canyon to the rim of the plateau near the headwaters of Sulphur Canyon is more than 1,800 feet.

The deeply dissected canyons and the afternoon heating of the steep upper slopes funneled the wind and the fire upslope.

Predicted Fire Behavior—Fire behavior was predicted using two standardized fire behavior guides available to all firefighters, the Incident Response Pocket Guide (figure 15) in the Pocket Guide, and the fire danger pocket card. More detailed fire behavior predictions were made using the BEHAVE and FARSITE fire prediction computer programs.

Figure 15 is reproduced from page 65 of the Pocket Guide. Actual weather variables captured by the Joe's Valley RAWS, for relative humidity and fuel moisture conditions were: 1-hour time-lag fuels, 1 percent; 10-hour time-lag fuels, 2 percent; relative humidity 5 to 11 percent. As the figure shows, dangerous burning conditions were predicted with extreme fire behavior possible.

RH %	1-hour FM%	10-hour FM%	Relative ease of chance of ignition and spotting; general burning conditions
<15	<5	<5	All sources of ignition dangerous; aggressively burning spot fires occur often and spread rapidly, extreme fire behavior probable; **critical** burning conditions

Figure 15—Severe fire behavior potential related to relative humidity (RH) and fuel moisture (FM) content.

Figure 16 shows the fire danger pocket card for the energy release component for fuel model H used in southeastern Utah. A similar card for fuel model F was issued by Moab dispatch. The card is for general firefighter use, and is generally used when briefing initial attack firefighters before they are dispatched to a fire. The card is used for risk assessment, linking fire danger to potential fire behavior.

Using the RAWS-generated national fire danger rating system values, the fire danger pocket cards issued by Moab dispatch predicted "extreme fire behavior when ERC is above 40" for fuel model H and to "anticipate extreme fire behavior when the BI is above 60" for fuel model F.

For the BEHAVE (figures 17 and 18) prediction, fuel model 2 (FM 2) was selected as the primary fuel model to predict fire behavior in the entrapment area. FM 2 models fire behavior in vegetation where the fire is spread primarily through fine herbaceous material but may also include stands that may include clumps of fuels that generate higher fire intensities and that may produce firebrands.

1-hour fuel moisture, 1 percent
10-hour fuel moisture, 2 percent
100-hour fuel moisture, 2 percent
Herbaceous, 30 percent
Midflame windspeed, 4 to 6 miles per hour
Slope, 4 to 20 percent

Figure 17—Inputs to calculate fuel model 2 fire behavior using BEHAVE software program.

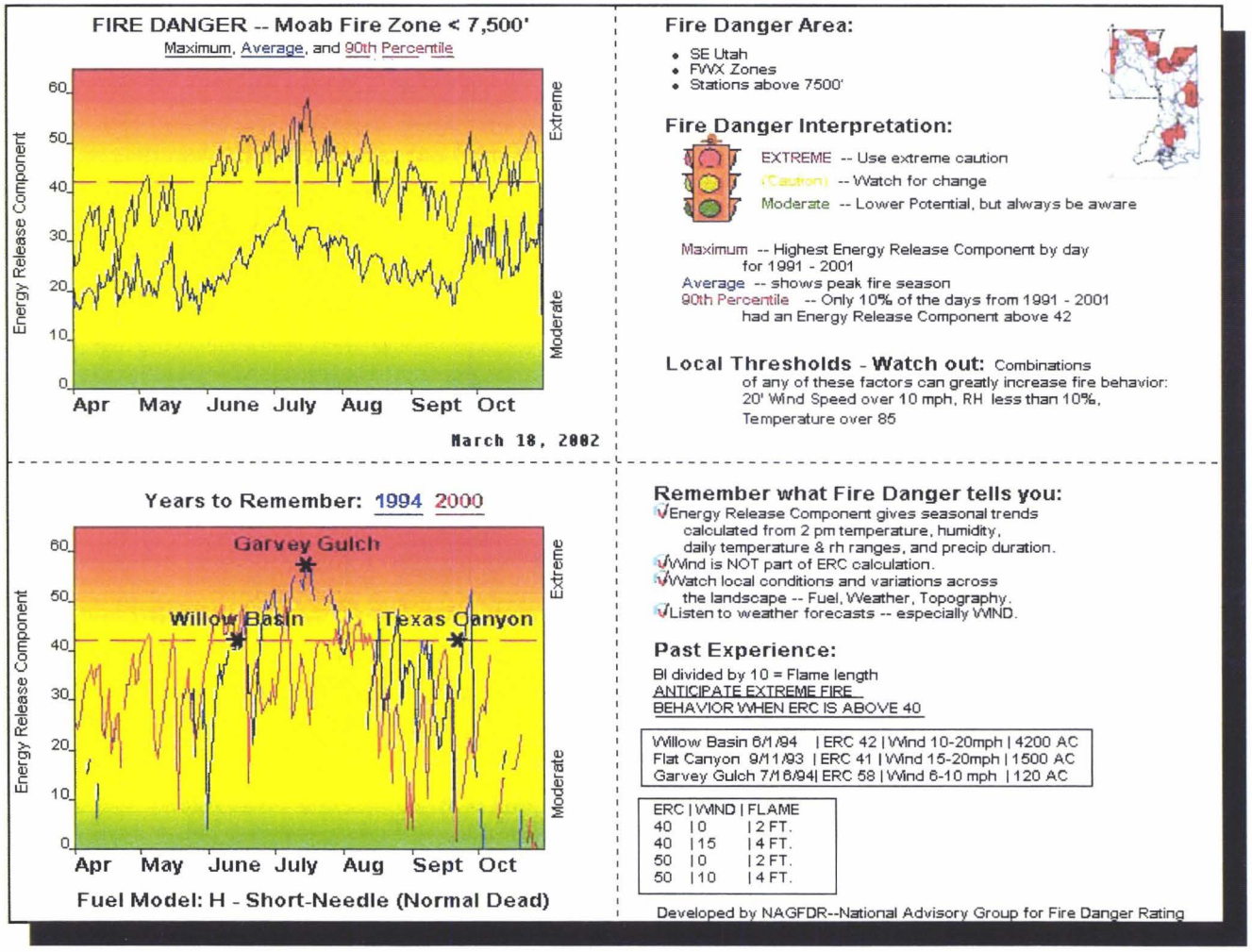
FIRE DANGER -- Moab Fire Zone < 7,500'
Maximum, Average, and 90th Percentile
Energy Release Component
Extreme
Moderate
Apr May June July Aug Sept Oct
March 18, 2002
Fire Danger Area:
SE Utah
FWX Zones
Stations above 7500'
Fire Danger Interpretation:
EXTREME -- Use extreme caution
(Caution) -- Watch for change
Moderate -- Lower Potential, but always be aware
Maximum -- Highest Energy Release Component by day for 1991 - 2001
Average -- shows peak fire season
90th Percentile -- Only 10% of the days from 1991 - 2001 had an Energy Release Component above 42
Local Thresholds - Watch out: Combinations of any of these factors can greatly increase fire behavior:
20' Wind Speed over 10 mph, RH less than 10%,
Temperature over 85
Years to Remember: 1994 2000
Garvey Gulch
Willow Basin
Texas Canyon
Fuel Model: H - Short-Needle (Normal Dead)
Remember what Fire Danger tells you:
Energy Release Component gives seasonal trends calculated from 2 pm temperature, humidity, daily temperature & rh ranges, and precip duration.
Wind is NOT part of ERC calculation.
Watch local conditions and variations across the landscape -- Fuel, Weather, Topography.
Listen to weather forecasts -- especially WIND.
Past Experience:
BI divided by 10 = Flame length
ANTICIPATE EXTREME FIRE BEHAVIOR WHEN ERC IS ABOVE 40
Willow Basin 6/1/94 | ERC 42 | Wind 10-20mph | 4200 AC
Flat Canyon 9/11/93 | ERC 41 | Wind 15-20mph | 1500 AC
Garvey Gulch 7/16/94| ERC 58 | Wind 6-10 mph | 120 AC
ERC | WIND | FLAME
40 | 0 | 2 FT.
40 | 15 | 4 FT.
50 | 0 | 2 FT.
50 | 10 | 4 FT.
Developed by NAGFDR--National Advisory Group for Fire Danger Rating

Figure 16—Fire danger pocket card.

Wind (mph)	Flame length (feet)	Rate of spread (feet per minute)
0.0	0.1	2
2.0	2.0	13
4.0	4.0	31
6.0	6.0	53
8.0	8.0	78

Figure 18—Fire behavior outputs for fuel model 2 using the BEHAVE software program.

A geospatial fire behavior prediction was made using the FARSITE computer model (figure 19). The fire's spread was calculated from 1500 to 2200 hours on June 30.

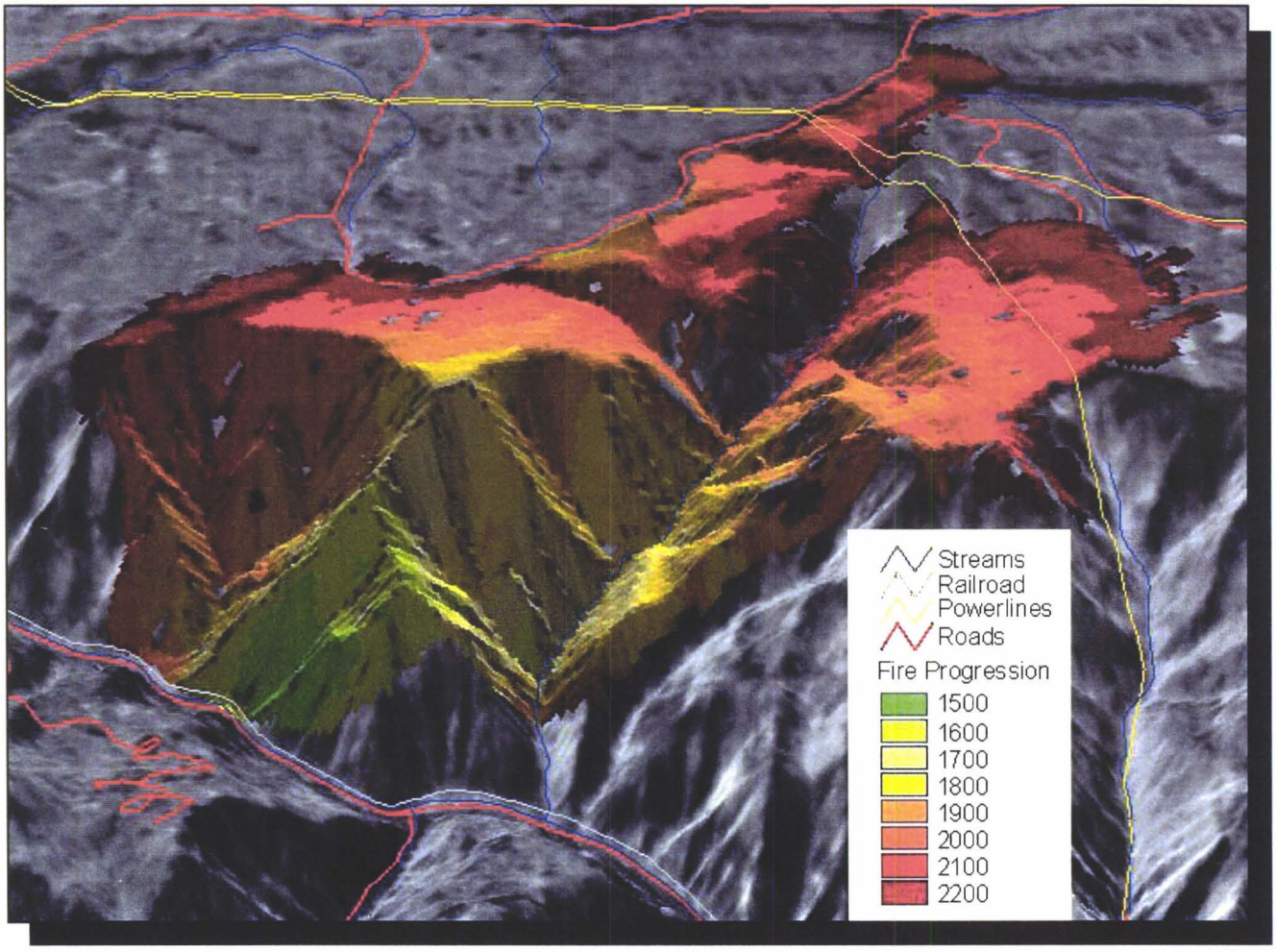

Figure 19—FARSITE computer model predicting the fire's spread from 1500 to 2200 on June 30, 2002.

Fire Behavior Chronology

1400—A train starts the fire ¼ mile south of the west bowl in Price Canyon. A single source ignition is imported into FARSITE, east of the railroad tracks and at the base of a small drainage running east to west.

1500—The fire spreads east, up the small drainage and onto the ridge. Fuel model (FM) 10 (Douglas fir) lofts several embers into Sulphur Canyon as well as a few into the west bowl. Size: 50 acres.

1600—The main fire continues to spread east along the ridgeline and toward the plateau. Spot fires in Sulphur Canyon grow and make small uphill runs, casting more embers. Spot fires in the bowl are few and are slowly backing down the slope in FMs 8 and 10 as well as making short uphill runs in FMs 6 and 10. Size: 200 acres.

1700—The main fire crests the ridge and moves onto the plateau, lofting embers out ahead of the flaming front. Fires in Sulphur Canyon spot across the creek and onto the north slope. In this area, fires are primarily slope-driven with some lateral movement up Sulphur Canyon. FM 10 continues to be the source of long-range spotting. Spot fires in the west bowl are observed by an aerial reconnaissance and continue their up-drainage runs, gradually spreading to the southeast. Smokejumpers begin firing the area to the southwest of the two-track road. Size: 500 acres.

1800—A line of fire about ¼ to ½ mile long and deep is now well established on the plateau (FMs 2 and 6) and moving downhill toward the smokejumpers' location. At the same time, the fire in Sulphur Canyon continues to make upslope runs on the south face and spreads to the east; spot fires on the north aspect of Sulphur Canyon (FMs 2, 5, 6, 8, and 10) spread to the ridgeline. Spot fires increase in the west bowl and fire spread is now transitioning from an upslope/flanking, southeasterly spread to runs to the east and northeast. The smokejumpers complete the firing out of the safety zone and two-track road, and three jumpers continue burning east along the main road. Size: 900 acres.

1900—At this time, four main fires are present: the fire on the plateau, the fire in Sulphur Canyon, the firing operation, and the fire in the west bowl. The fire on the plateau is within ¼ mile of the remaining five jumpers. Fire in Sulphur Canyon continues to spread to the east. Fire from the firing operation continues south, southeast toward the fire in Sulphur Canyon. The fire in the bowl has now spread to the entire bowl and is either midslope or cresting the ridge. At about 1910, two smokejumpers deploy fire shelters, and three smokejumpers run to the north due to the ember shower from the "collapsing" column and the accelerated head fire on the plateau. Size: 1,400 acres.

2000—The four main fires have converged into one fire and spread is limited, due in part, to the burnout to the north, the ridgelines and road to the west, and the ridgeline of Sulphur Canyon to the south. The rate of spread in Sulphur Canyon begins to slow due to an increase in relative humidity and an increase of FMs 5 and 8. Size: 2,000 acres.

2100—Fire spread is localized to a small area north of the west bowl, the area that the smokejumpers fired, and the main body of the fire in Sulphur Canyon. Size: 2,500 acres.

2200—Fire continues to spread to the east in Sulphur Canyon reaching the eastern flank (dirt road). Other areas of the fire experience limited growth. Size: 2,900 acres.

Fire Behavior Output

Time: 1400 to 2200 hours
Flame length*: 2 to 12 feet
Fireline intensity (Btu/ft/sec): 600 to 700
Heat per unit area (Btu/ft²): 900 to 1900
Rate of spread (ft/min): 5 to 60

*Surface fire

Fire Behavior Leading Up to the Deployment—The fire behavior described in this section was gathered from interviews with the smokejumpers and other firefighters associated with the fire action on June 30, study of photographs taken from a helicopter 2 days after the fire, viewing of a video taken by the smokejumpers just before they jumped, and analysis of photographs taken by a local newspaper journalist and a smokejumper just a few minutes before the deployment.

After the fire was started by a railroad train at 1400, it moved quickly to the northeast into Sulphur Canyon.

At the time of dispatch, the fire was estimated to be ¼ acre. At time of arrival of the first initial attack resources, the fire was estimated to be 20 to 25 acres.

The main fire burned to the ridgeline separating the west bowl from Sulphur Canyon in about 4 to 6 hours.

By 1630, most of Sulphur Canyon had burned out and the fire had burned most of the area east of the major ridge that separates Sulphur Canyon from the west bowl area.

The west bowl was the last large area to burn. Evidence suggests that the entire bowl did not burn at once. Initially, the fire made bottom-to-top runs on the east half of the west bowl. The rest of the bowl burned within an hour.

During reconnaissance of the fire area before jumping, the smokejumpers noted that the fire had burned to the ridge separating the west bowl from Sulphur Canyon. The fire had spread to this ridgeline just a short time before the jumper's arrival. Video footage taken by the smokejumpers from the jump aircraft shows a continuous line of smoke along this ridgeline. The video shows a spot fire over the ridgeline on a north-facing slope on the east side of the west bowl. This spot fire was in the lower third of the basin.

After the smokejumpers jumped and secured their gear, they began firing out from existing roads on the plateau between Sulphur Canyon and the west bowl. Fuels were primarily sagebrush and grass. The total area encompassed by the firing operation was estimated to be 300 to 600 acres.

At about 1900, the fire in the west bowl broached the rim of the canyon and began to burn onto the sagebrush plateau, igniting a line of fire about ½ mile long. As seen in figure 6, this fire is burning downhill toward the smokejumpers.

The fire behavior experienced by the jumpers prior to and during the entrapment was caused by three separate influences.

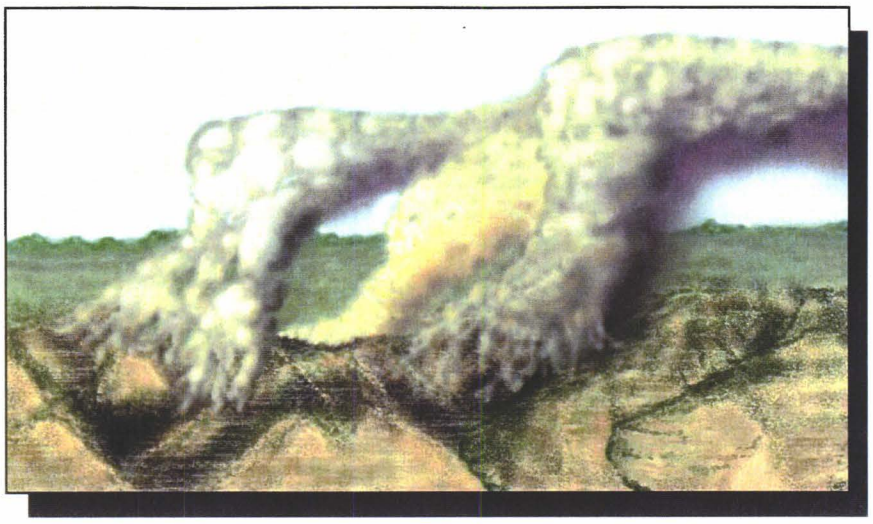

Figure 20—Artist rendering of the Price Canyon smoke columns.

As the fuels in the west bowl were consumed and the column of smoke rose above the rim of the west bowl, the fire lost its source of energy and support. Most of the fuel was consumed and the smoke column collapsed, blasting a gust of smoke, hot air, and embers to the east.

As the column of smoke rose over the rim of the west bowl, it was caught in the afternoon westerly winds. This smoke was both blown into and drawn into the column of heat and smoke rising from the smokejumper firing operation and the main fire in Sulphur Canyon (figure 20).

As the column collapsed and fell toward the ground, it accelerated the rate of spread of the ground fire burning over the rim of the west bowl, pushing the ground fire toward the smokejumpers.

The smokejumpers noticed fire whirls burning at the intersection of the rim of the west bowl and the sagebrush plateau.

After the smokejumpers were entrapped, the fire continued to burn downhill in sagebrush and grass to the north and northeast. When the wind from the fire abated, the fire stopped spreading.

Fire Behavior Discussion—The fire spread very quickly with high rates of spread on the slopes of the steep canyons, and moderate rates of spread and moderate fireline intensities on the flat sagebrush/grass plateaus above the canyon in the entrapment area.

Some firefighters reported seeing a cumulus cap over the Sulphur Canyon smoke column, an indication of a plume-dominated fire with the potential for violent downbursts. Even though a relatively high Haines index with a low wind speed was predicted for June 30, a microburst was ruled out as being the cause of the entrapment.

None of the smoke columns reviewed in the photographs indicated that they rose to critical elevations needed for downburst development.

After validating the fire weather forecast with a meteorologist at the Salt Lake office of the National Weather Service, thunderstorm winds were also ruled out as a source of the 50-mile-an-hour-plus winds reported during the deployment.

Fire whirls could have caused the blast of hot air and embers to descend on the jumpers. Jumpers said they saw fire whirls in the area at the time of the entrapment.

Evidence indicates that the smokejumper entrapment was caused by the collapse of the west bowl smoke column. The hot air and gases from the collapsing column suddenly accelerated the ground fire on the plateau east of the rim, pushing the ground fire and hot air and embers toward the east.

The fire behavior analysis, photographs, video, and witness statements indicate that the smoke column billowing out of the west bowl, after first being caught in the westerly prevailing winds, was drawn into the smoke column created by the jumper's firing operation.

Few firefighters have been exposed to the type of life-threatening conditions that the five jumpers experienced. However, it must be noted, every fire behavior tool readily available to initial attack firefighters—from the fire danger pocket cards to prediction charts in the Pocket Guide— predicted the potential for extreme fire behavior on the Price Canyon fire.

Finally, a case could be made that the heavy grazing in the fire area may have limited the fire intensity and rate of spread.

Fire Shelter Report

Two firefighters deployed their fire shelters while working the Price Canyon fire on June 30, 2002. The two fire shelters were inspected by fire equipment specialist Tony Petrilli from the Missoula Technology and Development Center (MTDC). Tony also conducted telephone interviews with the two firefighters.

Shelter 1, Firefighter Matt Lowe—
Manufacturer: Weckworth/Langdon
Contract number: GS07F-76290
Lot No. 0001
Date of manufacture: 1995

The shelter appears to be in good condition with the normal amount of pinholes, as expected in this type of deployment. The sewn seam of the sod cloth was faulty. The sod cloth was not caught in the seam making an 18-inch gap. There was no visible heat damage, so temperatures during deployment were less than 500 °F. The shelter appears to have performed as designed.

Shelter 1, Firefighter Tom Dwyer—
Manufacturer: International Cases
Serial number: S62477S
Date of manufacture: November 1999

The shelter appears to be in good condition with few pinholes, as expected in this type of deployment. All sewn seams are in good condition. There are two areas of slight discoloration on parts of the fire shelter that, when fully deployed, contact the ground.

The sizes of the discolored areas were a 2- by 4-inch and a 1- by 1-inch spot. The cause of the discoloration may be hot ground that was reported by the firefighter. The shelter appears to have performed as designed. According to the firefighters, both firefighters were equipped with proper personal protective equipment (PPE). The firefighters escaped into a large area that they had burned as a safety zone 1 hour before. During the escape, one firefighter pulled his shelter from his pack and had it in his hand. The deployment sequence was not frantic. The deployment site was about 50 yards inside the edge of their safety zone. The fire's initial blast came with 50-mile-per-hour winds, smoke, ash, and many hot embers some as big as baseballs.

The firefighters reported that the initial blast was by far the worst. Both firefighters opened their shelters and put their legs and arms through the straps. Although the windspeed was high, they did not report much difficulty in the deployment. With the fire shelters on their backs like a turtle shell, they used handtools to clear an area for deployment. While fully deployed, one firefighter experienced ground heat that was uncomfortable, so he proceeded to crouch inside his shelter. The other firefighter was able to fully deploy in the prone position. A few blasts with fire whirls came near the deployment area. Between blasts, the firefighters periodically peered out of their fire shelters. The firefighters felt that the entrapment was survivable without the fire shelter, but deployed their fire shelters to make the situation more bearable and to increase their comfort level from smoke, ash, and embers. The firefighters did not want to take a chance with the fire whirls that were in the area. Both firefighters thought deploying their fire shelters was a reasonable action to take. The thought of an investigation did enter the mind of one firefighter.

The firefighters were able to be in close contact with each other during the deployment. That contact reportedly helped their situation. During the deployment they were concerned about the condition of the other firefighters because they were initially unable to establish radio contact with anyone else.

Training—Both firefighters had received fire shelter training before the fire season. Both firefighters had practiced deployments behind a DC-3 aircraft that generated 40-mile-per-hour winds. Both firefighters had seen the 'Your Fire Shelter: 2001' training video.

Compliance With 10 Standard Fire Orders

Standard Fire Order	Discussion
Fight fire aggressively but provide for safety first.	The fire was fought aggressively. A preoperational briefing among the jumpers included a discussion of LCES and strategy. A safety zone was burned out for the jumpers and their gear and was later used as a deployment site by two of the jumpers.
Initiate all action based on current and expected fire behavior.	Actions taken were based on the firefighters' assessment of current and expected fire behavior. Although the jumpers identified that fire in the west bowl could jeopardize their anchor point, they did not expect the sudden, severe conditions that eventually resulted.
Recognize current weather conditions and obtain forecasts.	Current weather conditions were observed. The jumpers had received the morning fire weather forecast in Cedar City.
Ensure instructions are given and understood.	The transition between type III incident commanders hampered communications and situation awareness at a critical time. When the jumpers arrived on the fire, they received their initial orders from the first IC. They formed a plan, briefed, and began firing the area to the south and east of the road intersection.
Obtain current information on fire status.	The jumpers sized up the fire while orbiting before the jump, but they were not able to maintain a clear picture of the entire fire after they got on the ground. The jumpers posted a lookout to watch the immediate area of their operations. Fixed- and rotary-wing aircraft provided an intermittent observation platform, but no aircraft were over the fire at the time of the sudden wind and fire behavior increase. The transition in command made it necessary for the second incident commander to gather information and perform an incident analysis, which consumed a great deal of time during a critical period.
Remain in communication with crewmembers, your supervisor, and adjoining forces.	Due to a mechanical problem, air attack was not available to relay communications during the firing operation. Knowledge of actions of other resources on the fire and communication with adjoining forces was disjointed. There was limited communication between the jumpers and the IC(s). Not all firefighters on the fire could monitor the jumper crew frequency, which was used by the jumpers in addition to the assigned tactical frequency. Visual and radio contact was maintained among five of the jumpers during the firing operation. The other three jumpers quickly traveled out of sight but could still communicate with the other jumpers by radio.

(Continued)

Standard Fire Order	Discussion
Determine safety zones and escape routes.	The jumpers established a safety zone consistent with guidelines for radiant heat protection per the Incident Response Pocket Guide. The burned-out area to the southeast of the road intersection was the primary safety zone, and the two-track road to the north of the intersection was a secondary escape route. The burned-out area was later revealed to be inadequate as a safety zone. Convective gases, embers, and firewhirls forced the two jumpers who took refuge there to deploy fire shelters.
Establish lookouts in hazardous situations.	There were not assigned lookouts in place who could see the entire fire. Although the west bowl had been identified by the jumpers as a potential problem, there was not a lookout in position who could see into the bowl and inform other firefighters of impending danger. The jumpers established a lookout to watch over the area of their firing operation. The jumper who had been assigned as a lookout left his position and rejoined the other four jumpers at the road intersection just before the sudden wind and fire behavior increase.
Retain control at all times	A transition between incident commanders at a critical time, limited resources, less than adequate communications, and extreme fire behavior on a rapidly growing fire made it difficult for the incident commander to retain control of firefighter actions on this fire. A large-scale firing operation was underway when the second IC assumed command.
Stay alert, keep calm, think clearly, act decisively.	Of the five individuals directly involved in the entrapment, all were aware of the hazardous situation and acted decisively. The three jumpers who ran to the north stated that the first few minutes of the event were frightening and that they felt they were running for their lives. The two jumpers who took refuge in the black deployed their shelters to protect themselves from firewhirls and hazards associated with the wind-borne debris.

Compliance With 18 Watchout Situations

18 Watchout Situations	Comments
Fire not scouted and sized up.	The fire was initially scouted and sized up by both incident commanders and the jumpers, but no one maintained awareness of the entire incident as the fire increased in size and complexity.
In country not seen in daylight.	Not an issue.
Safety zones and escape routes not identified.	A safety zone was established consistent with guidelines for radiant heat protection per the Incident Response Pocket Guide. Strong winds, fire whirls, convective gases and burning debris transported by the smoke column compromised the safety zone. It became necessary to deploy fire shelters in order to maintain a margin of safety; by definition it was no longer a safety zone. The strategy of burning out a safety zone and the two-track road used as an escape route to the north were noted by the jumpers in their preoperational briefing.
Unfamiliar with weather and local factors influencing fire behavior.	The jumpers were generally familiar with fuels in the fire area. The sudden wind and fire behavior increase was not anticipated by the five jumpers it affected. They had been briefed about the extremely low live and dead fuel moisture levels recorded locally. The general weather forecast for the area was read at the jumpers' morning briefing. No spot weather forecast was requested by either Incident Commander.
Uninformed on strategy, tactics, and hazards.	Basic strategy for the west end of the fire was determined by the jumpers and approved by the first incident commander by radio transmission. Some hazards such as powerlines and methane vents in the vicinity were known and communicated.
Instructions and assignments not clear	There was not a clear objective for suppression actions that was communicated to all firefighters on the incident. A transition between type III incident commanders occurred as the jumpers arrived on the fire. Instructions from the first IC to the jumpers were minimal, and did not conflict with the jumpers' assessment of what needed to be done. After assuming command, the second IC went on a helicopter reconnaissance flight. He observed the jumpers' firing operation and told the jumpers that he approved of what they were doing.
No communications link with crewmembers/supervisor.	There was not a command repeater frequency in use on the incident, nor was there a person in position to act as a relay between personnel on different parts of the fire. Line-of-sight tactical and jumper crew frequency communications deteriorated as the fire grew larger and distances between personnel increased. During the shelter deployment, the two jumpers who deployed were initially unable to contact anyone else on the fire. About 20 minutes after the two jumpers deployed, the air tactical group supervisor arrived over the fire and established radio communications between the jumpers and other firefighters.
Constructing fireline without safe anchor point.	The strategy of firing the area to the south and east of the four-way road intersection was based on using the road intersection as an anchor point for the west end of the fire. Once the fire became established in the west bowl, that anchor point was no longer secure.

(Continued)

18 Watchout Situations	Comments
Building fireline downhill with fire below.	Not an issue.
Attempting frontal assault on fire.	Not an issue.
Unburned fuel between you and the fire.	The jumpers' firing operation was designed to remove unburned fuels between the main fire and the east-west dirt road used as a control line. Their firing operation was initially successful, and a large portion of the north flank between the four-way intersection and the head of Sulphur Canyon was successfully fired. Once the fire became established in the west bowl and emerged onto the plateau, the anchor for this line was no longer secure. There was a great deal of unburned fuel between the four-way road intersection anchor point and the west bowl.
Cannot see main fire, not in contact with anyone who can.	Initially, one of the jumpers served as a lookout for the immediate area of jumper operations, but he could not see the entire fire. Air resources provided intermittent lookout capability but there were no ground-based lookouts who could see the entire fire. There were no lookouts either on the ground or in the air at the time of the sudden wind and fire behavior increase.
On a hillside where rolling material can ignite fuel below.	Not an issue.
Weather is getting hotter and drier.	The weather was getting hotter and drier during the afternoon. Weather observations for the afternoon of June 30 from a nearby RAWS weather station at 8,700 feet: temperature, 80 °F; relative humidity, 5 percent; average wind, 12 miles per hour from the west.
Wind increases and/or changes direction.	Wind was generally 5 to 15 miles per hour from the west except during the sudden increase in fire behavior at the road intersection (gusts estimated at over 50 miles per hour).
Getting frequent spot fires across line.	Was not an issue until the sudden surge of fire activity started multiple spot fires. The three jumpers who escaped to the north were subjected to strong winds, smoke, and a shower of embers when the column enveloped them. One jumper jettisoned his pack about 150 feet north of the east-west road. The pack was completely consumed by fire. The spotfires in this area merged into a strip of fire several hundred feet wide that paralleled the east-west road. The two jumpers who took refuge in the black stated that fire was burning in the sage/oak fuels north of the intersection within seconds after the sudden wind increase.
Terrain and fuels make escape to safety zones difficult.	The three jumpers who escaped toward the north were initially exposed to dense smoke, strong winds, and a shower of embers and debris. Having a cleared path (the road) and a gentle downhill slope were positive aspects of this escape route. Running through unburned fuels to a distant secondary safety zone were negative aspects of this escape route.
Taking a nap near the fireline.	Not an issue.